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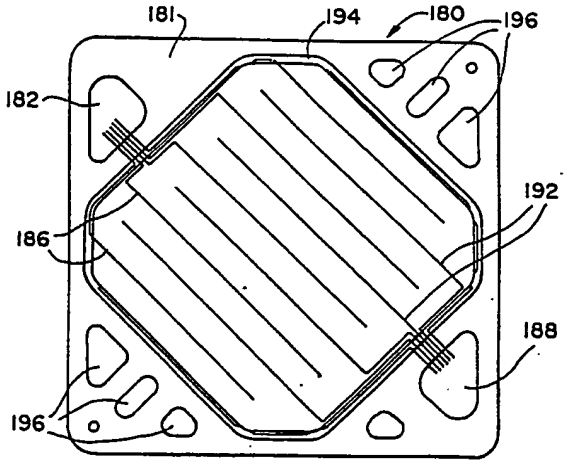

(57) Abstract

Fluid flow field plates (180) for electrochemical fuel cells incorporate discontinuous fluid flow channels. The plates are formed from an electrically conductive, fluid impermeable material having a major surface in which at least one inlet channel (186) extends from a pressurized fluid reactant inlet (182). At least one outlet channel (192) extends from a fluid reactant outlet (188) formed in the major surface. Each inlet channel is discontinuous with respect to each outlet channel. The pressurized fluid reactant is urged through the interstices of the adjacent porous electrode material between each inlet channel and each outlet channel. The discontinuous flow field channels can also be formed in the surface of the electrode, in which case the flow field plates are replaced with thinner, electrically conductive, fluid impermeable separator plates.

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FUEL CELL FLUID FLOW FIELD PLATE WITH DISCONTINUOUS FLUID FLOW CHANNELS.

Field Of The Invention

The present invention relates to electrochemical fuel cells. More particularly, the present invention relates to fluid flow field plates incorporating discontinuous fluid flow channels and corresponding electrode assemblies for use in electrochemical fuel cells.

Background Of The Invention

Electrochemical fuel cells convert fuel and oxidant to electricity and reaction product. In electrochemical fuel cells employing hydrogen as the fuel and oxygen as the oxidant, the reaction product is water. Such fuel cells generally employ a membrane electrode assembly ("MEA") consisting of a solid polymer electrolyte or ion exchange membrane disposed between two electrodes formed of porous, electrically conductive sheet material, typically carbon fiber paper. The MEA contains a layer of catalyst, typically in the form of finely comminuted platinum, at each membrane/electrode interface to induce the desired electrochemical reaction. The electrodes are electrically coupled to provide a path for conducting electrons between the electrodes through an external load.

At the anode, the fuel permeates the porous electrode material and reacts at the catalyst layer to form cations, which migrate through the membrane to the cathode. At the cathode, the oxygen-

containing gas supply reacts at the catalyst layer to form anions. The anions formed at the cathode react with the cations to complete the electrochemical reaction and form a reaction product.

In electrochemical fuel cells employing hydrogen as the fuel and oxygen-containing air (or substantially pure oxygen) as the oxidant, the catalyzed reaction at the anode produces hydrogen cations (protons) from the fuel supply. The ion exchange membrane facilitates the migration of hydrogen ions from the anode to the cathode. In addition to conducting hydrogen ions, the membrane isolates the hydrogen-containing fuel stream from the oxygen-containing oxidant stream. At the cathode, oxygen reacts at the catalyst layer to form anions. The anions formed at the cathode react with the hydrogen ions that have crossed the membrane to complete the electrochemical reaction and form liquid water as the reaction product.

The MEA is interposed between two fluid-impermeable, electrically conductive plates, commonly referred to as the anode and the cathode plates, respectively. The plates serve as current collectors, provide structural support for the porous, electrically conductive electrodes, provide means for carrying the fuel and oxidant to the anode and cathode, respectively, and provide means for removing water formed during operation of the fuel cell. When the channels are formed in the anode and cathode plates, the plates are referred to as fluid flow field plates. When the anode and cathode plates overlay channels formed in the anode and cathode porous material, the plates are referred to as separator plates.

Reactant feed manifolds are generally formed

in the anode and cathode plates, as well as in the MEA, to direct the fuel (typically substantially pure hydrogen or hydrogen-containing reformate from the conversion of hydrocarbons such as methanol and natural gas) to the anode and the oxidant (typically substantially pure oxygen or oxygen-containing gas) to the cathode via the channels formed in either the fluid flow field plates or the electrodes themselves. Exhaust manifolds are also generally formed in the anode and cathode plates, as well as the MEA, to direct unreacted fuel and oxidant, as well as water accumulated at the cathode, from the fuel cell.

Multicell assemblies comprising two or more anode plate/MEA/cathode plate combinations, referred to as a fuel cell stack, can be connected together in series (or in parallel) to increase the overall power output as required. In such stack arrangements, the cells are most often connected in series, wherein one side of a given fluid flow field or separator plate is the anode plate for one cell, the other side of the plate is the cathode plate for the adjacent cell, and so on.

Perfluorosulfonic ion exchange membranes, such as those sold by DuPont under its Nafion trade designation, have been used effectively in electrochemical fuel cells. Fuel cells employing Nafion-type cation exchange membranes require accumulated water to be removed from the cathode (oxidant) side, both as a result of the water transported across the membrane with cations and product water formed at the cathode from the electrochemical reaction of hydrogen cations with oxygen. A new type of experimental

perfluorosulfonic ion exchange membrane, sold by Dow under the trade designation XUS 13204.10, appears to have significantly less water transported with hydrogen cations across the membrane. Fuel cells employing the Dow experimental membrane thus tend to accumulate less on the cathode (oxidant) side, as the accumulated water at the cathode is essentially limited to product water formed from the electrochemical reaction of hydrogen and oxygen.

A typical prior art fluid flow field plate, exemplified by General Electric Company and Hamilton Standard in a 1984 report for the U.S. Department of Energy (LANL No. 9-X53-D6272-1), included a plurality of parallel open-faced fluid flow channels formed in a major surface of the plate. The parallel channels extended between an inlet header and an outlet header formed in the plate. The parallel channels were typically rectangular in cross-section, and about 0.03 inches deep and about 0.03 inches wide. The inlet header was connected to an opening in the plate through which a pressurized reactant (fuel or oxidant) stream is supplied. The outlet header was connected to an opening in the plate through which the exhaust stream is discharged from the cell. In operation, the reactant stream ran from the inlet to the inlet header and then to the parallel channels from which reactant from the stream diffused through the porous electrode material to the electrocatalytically active region of the MEA. The stream then flowed to the outlet header and then to the outlet from which it was exhausted from the fuel cell.

The 1984 GE/Hamilton Standard flow field plate had inherent disadvantages. When employed as the cathode plate, water coalesced in some of the channels adjacent the cathode surface, thereby obstructing those channels and blocking the flow of the reactant stream through the obstructed channels. Water tended to further collect, enlarging into droplets in the obstructed channels, and dead spots formed at various regions of the electrode because of the inadequate reactant flow. The 1984 GE/Hamilton Standard flow field plate thus suffered from non-uniform reactant flow across the electrode surface and insufficient water removal due to the coalescing of water in the channels adjacent the cathode.

Watkins U.S. Patent Nos. 4,988,583 and 5,108,849 issued January 29, 1991 and April 28, 1992, respectively, describe fluid flow field plates which include a fluid supply opening and a fluid exhaust opening formed in the plate surface. Continuous open-faced fluid flow channels formed in the surface of the plate traverse the central area of the plate surface in a plurality of passes, that is, in a serpentine manner. Each channel has a fluid inlet at one end and a fluid outlet at the other end. The fluid inlet and outlet of each channel are directly connected to the fluid supply opening and fluid exhaust opening, respectively. The Watkins continuous channel design promotes the forced movement of water through each channel before the water can coalesce. The Watkins design therefore promotes uniform reactant flow across the surface of the cathode. However, the length of the serpentine channels in the Watkins design requires

a large pressure drop between the inlet and the outlet, thus creating the need for pressurization of the reactant supplies. In fuel cell based power generation systems, the power to pressurize the reactants represents a significant parasitic load which can reduce the amount of power otherwise available for delivery to an external electrical load.

In the prior art designs described above, the reactants are delivered to the electrodes via channels formed in flow field plates adjacent the electrode surface. The prior art designs rely upon the diffusion of the reactant molecules through the thickness of the porous electrode structure to the electrocatalytically active region at the membrane/electrode interface. Moreover, the landing areas of the fluid flow field plates, that is, the areas between the reactant flow channels, often provide inadequate access to the flow of reactants. Similarly, insufficient access of the reactant stream to the electrode structure adjacent the landing areas results in the removal of water from those areas of the electrode at a lower rate than could be achieved with improved reactant stream access near the landing areas.

Accordingly, it is an object of the invention to provide an improved flow field design that provides better access of the reactant stream to the internal structure of the electrode, particularly the electrocatalytically active region at the membrane/electrode interface.

Another object of the invention is to provide an improved flow field design that provides improved water removal capability because of the

better access of the reactant stream to the internal structure of the electrode.

A further object of the invention is to provide an improved fluid flow field plate design that provides improved mechanical support to the membrane electrode assembly adjacent the flow field plate.

Summary Of The Invention

The above and other objects are achieved by a fluid flow field plate for an electrochemical fuel cell in which the inlet and outlet flow channels are discontinuous. The plate has an inlet for introducing a fluid to a major surface of the plate and an outlet for discharging fluid from the major surface. The major surface has formed therein at least one inlet channel extending from the inlet and at least one outlet channel extending from the outlet. The at least one inlet channel is discontinuous with respect to the at least one outlet channel. The plate is preferably formed of electrically conductive material.

An electrode assembly for an electrochemical fuel cell is provided in which at least one of the reactant flow field plates (the anode or the cathode flow field plate) employs discontinuous flow channels. The assembly comprises:

an inlet for introducing a pressurized fluid reactant stream to the assembly;

an outlet for discharging the fluid reactant stream from the assembly;

a layer of electrically conductive material permeable to the fluid reactant, the fluid permeable layer having a major surface;

a layer of electrically conductive material substantially impermeable to the fluid reactant, the fluid impermeable layer having formed in a major surface thereof at least one inlet channel extending from the inlet and at least one outlet channel extending from the outlet, wherein the at least one inlet channel is discontinuous with respect to the at least one outlet channel, the fluid permeable and fluid impermeable layers contacting each other at their respective major surfaces.

The fluid reactant is urged through the interstices of the fluid permeable layer between the at least one inlet channel and the at least one outlet channel.

An electrode assembly for an electrochemical fuel cell is provided in which at least one of the electrodes (the anode and/or the cathode) has discontinuous flow channels formed therein. The assembly comprises:

an inlet for introducing a pressurized fluid reactant stream to the assembly;

an outlet for discharging the fluid reactant stream from the assembly;

a layer of electrically conductive material permeable to the fluid reactant, the fluid permeable layer having formed in a major surface thereof at least one inlet channel extending from the inlet and at least one outlet channel extending from the outlet, wherein the at least one inlet channel is discontinuous with respect to the at least one outlet channel;

a layer of electrically conductive material substantially impermeable to the fluid reactant, the fluid impermeable layer having a major surface, the fluid permeable and fluid impermeable layers contacting each other at their respective major surfaces.

The fluid reactant is urged through the interstices of the fluid permeable layer between the at least one inlet channel and the at least one outlet channel.

An electrochemical fuel cell is provided in which the cathode flow field plate employs discontinuous flow channels. The fuel cell comprises:

(a) an anode assembly having a catalyst associated therewith to render a region of the anode electrocatalytically active wherein cations are produced from a fuel;

(b) a cathode assembly comprising:

an oxidant inlet for introducing a pressurized fluid oxidant stream to the cathode assembly;

an oxidant outlet for discharging the fluid oxidant stream from the cathode assembly;

a layer of electrically conductive material permeable to the oxidant, the oxidant permeable layer having a major surface, the oxidant permeable layer having a catalyst associated therewith to render a region of the cathode electrocatalytically active wherein an electrochemical reaction between the cations and the oxidant is promoted;

a layer of electrically conductive material substantially impermeable to the oxidant, the oxidant impermeable layer having formed in a major surface thereof at least one oxidant inlet channel extending from the oxidant inlet and at least one oxidant outlet channel extending from the oxidant outlet, wherein the at least one oxidant inlet channel is discontinuous with respect to the at least one oxidant outlet channel, the oxidant permeable and oxidant impermeable layers contacting each other at their respective major surfaces;

whereby the oxidant is urged through the interstices of the oxidant permeable layer between the at least one oxidant inlet channel and the at least one oxidant outlet channel;

(c) a solid polymer ion exchange membrane disposed between the anode assembly and the cathode assembly, the membrane facilitating the migration of cations from the anode assembly to the cathode assembly and isolating the fuel from the fluid oxidant stream; and

(d) an electrical path for conducting electrons formed at the anode assembly to the cathode assembly.

The fuel cell can also include an anode flow field plate employing discontinuous flow channels. The corresponding anode assembly comprises:

a fuel inlet for introducing a pressurized fluid fuel stream to the anode

assembly;

a fuel outlet for discharging the fuel stream from the assembly;

a layer of electrically conductive material permeable to the fuel, the fuel permeable layer having a major surface,

a layer of electrically conductive material substantially impermeable to the fuel, the fuel impermeable layer having a major surface, the fuel permeable and fuel impermeable layers contacting each other at their respective major surfaces;

whereby the fuel is urged through the interstices of the fuel permeable layer between the at least one fuel inlet channel and the at least one fuel outlet channel.

An electrochemical fuel cell is provided in which the cathode has discontinuous flow channels formed therein. The fuel cell comprises:

(a) an anode assembly having a catalyst associated therewith to render a region of the anode electrocatalytically active wherein cations are produced from a fuel;

(b) a cathode assembly comprising:

an oxidant inlet for introducing a pressurized fluid oxidant stream to the cathode assembly;

an oxidant outlet for discharging the fluid oxidant stream from the cathode assembly;

a layer of electrically conductive material permeable to the oxidant, the oxidant permeable layer having a catalyst associated therewith to render a region

of the cathode electrocatalytically active wherein an electrochemical reaction between the cations and the oxidant is promoted, the oxidant permeable layer having formed in a major surface thereof at least one oxidant inlet channel extending from the oxidant inlet and at least one oxidant outlet channel extending from the oxidant outlet, wherein the at least one oxidant inlet channel is discontinuous with respect to the at least one oxidant outlet channel;

a layer of electrically conductive material substantially impermeable to the oxidant, the oxidant impermeable layer having a major surface, the oxidant permeable and oxidant impermeable layers contacting each other at their respective major surfaces;

whereby the oxidant is urged through the interstices of the oxidant permeable layer between the at least one oxidant inlet channel and the at least one oxidant outlet channel;

(c) a solid polymer ion exchange membrane disposed between the anode assembly and the cathode assembly, the membrane facilitating the migration of cations from the anode assembly to the cathode assembly and isolating the fuel from the fluid oxidant stream; and

(d) an electrical path for conducting electrons formed at the anode assembly to the

cathode assembly.

The anode of the fuel cell described above can also have discontinuous flow channels formed therein. The corresponding anode assembly comprises:

a fuel inlet for introducing a pressurized fluid fuel stream to the anode assembly;

a fuel outlet for discharging the fluid fuel stream from the assembly;

a layer of electrically conductive material permeable to the fuel, the fuel permeable layer having formed in a major surface thereof at least one fuel inlet channel extending from the fuel inlet and at least one fuel outlet channel extending from the fuel outlet, wherein the at least one fuel inlet channel is discontinuous with respect to the at least one fuel outlet channel;

a layer of electrically conductive material substantially impermeable to the fuel, the fuel impermeable layer having a major surface, the fuel permeable and fuel impermeable layers contacting each other at their respective major surfaces;

whereby the fuel is urged through the interstices of the fuel permeable layer between the at least one fuel inlet channel and the at least one fuel outlet channel.

In a preferred embodiment of the fluid flow field plate, electrode assembly and fuel cell, the inlet and outlet channels extend from headers. In the preferred header embodiment, the at least one inlet channel comprises an inlet header channel

extending from the fluid inlet and a plurality of inlet branch channels extending from the inlet header channel. Similarly, the at least one outlet channel preferably comprises an outlet header channel extending from the fluid outlet and a plurality of outlet branch channels extending from the outlet header channel.

In a more preferred embodiment of the fluid flow field plate, electrode assembly and fuel cell, the flow channels are discontinuous and interdigitated. In the preferred interdigitated embodiment, the at least one outlet channel comprises a plurality of separate outlet channels, each pair of adjacent outlet channels having an inlet channel disposed therebetween along a substantial portion thereof. In the preferred interdigitated embodiment, the at least one outlet channel comprises at least three separate outlet channels and each inlet channel disposed between each pair of adjacent outlet channels is separate with respect to the remainder of the inlet channels.

In a most preferred embodiment of the electrode assembly and fuel cell, the inlet channels and the fuel outlet channels are substantially parallel along the portions of the channels adjacent the electrocatalytically active region, and the channels do not converge toward the respective inlet and outlet openings in the area of the plate adjacent the electrocatalytically active region.

Brief Description Of The Drawings

FIG. 1 is a side elevation view of a fuel cell stack showing the electrochemically active and humidification sections.

FIG. 2 is an exploded side view of a fuel cell including a membrane electrode assembly interposed between two fluid flow field plates having reactant flow channels formed in the surfaces facing the electrodes.

FIG. 3 is an exploded side view of a fuel cell including a membrane electrode assembly having integral reactant flow channels interposed between two separator layers.

FIG. 4 is a top plan view of a fluid flow field plate having a single continuous open-faced channel that traverses the central area of the plate in a plurality of passes between a fluid inlet directly connected to a fluid supply opening and a fluid outlet directly connected to a fluid exhaust opening, as described in Watkins U.S. Patent No. 4,988,583.

FIG. 5 is an enlarged sectional view of the channels formed in the surface of the fluid flow field plate illustrated in FIG. 2.

FIG. 6 is a top plan view of a fluid flow field plate having multiple continuous open-faced channel, each of which traverses the central area of the plate in a plurality of passes between a fluid inlet directly connected to a fluid supply opening and a fluid outlet directly connected to a fluid exhaust opening, as described in Watkins U.S. Patent No. 5,108,849.

FIG. 7 is a top plan view of one embodiment of

a fluid flow field plate having discontinuous fluid flow channels extending from inlet and outlet headers in fluid communication with a fluid inlet opening and a fluid outlet opening, respectively.

FIG. 8 is a top plan view of a second embodiment of a fluid flow field plate having 11 discontinuous, interdigitated fluid flow channels, 5 channels of which are inlet channels extending from a fluid inlet opening and 6 channels of which are outlet channels extending from a fluid outlet opening, each of the inlet channels being disposed between a pair of outlet channels.

FIG. 9 is a top plan view of a third embodiment of a fluid flow field plate having 7 discontinuous fluid flow channels, 3 channels of which are inlet channels extending from a fluid inlet opening and 4 channels of which are outlet channels extending from a fluid outlet opening. The electrocatalytically active region of the electrode is located adjacent the area of the plate where the channels are parallel and do not converge toward the respective inlet and outlet openings.

FIG. 10 is a plot of cell voltage as a function of current density for a fuel cell operated with (A) as a baseline, the 10 channel (continuous) cathode flow field plate illustrated in FIG. 6 and a similar 2 channel (continuous) anode flow field plate at 30/30 psig (air/H_2), (B) the 11 channel (discontinuous) cathode flow field plate illustrated in FIG. 8 and a 2 channel (continuous) anode flow field plate at 30/30 psig (air/H_2), (C) as another baseline, the 10 channel (continuous) cathode flow field plate illustrated in FIG. 6 and a similar 2 channel (continuous)

anode flow field plate at 60/60 psig (air/H_2), and (D) the 11 channel (discontinuous) cathode flow field plate illustrated in FIG. 8 and a 2 channel (continuous) anode flow field plate at 60/60 psig (air/H_2).

FIG. 11 is a plot of cell voltage as a function of current density for a fuel cell operated with (E) as a baseline, the 10 channel (continuous) cathode flow field plate illustrated in FIG. 6 and a similarly configured 2 channel (continuous) anode flow field plate, (F) the cathode flow field plate illustrated in FIG. 8 and a 2 channel (continuous) anode flow field plate, and (G) the cathode flow field plate illustrated in FIG. 9 and a 2 channel (continuous) anode flow field plate.

FIG. 12 is a plot of cell voltage as a function of current density for a fuel cell operated with (H) the cathode flow field plate illustrated in FIG. 9 formed of solid graphite and a 2 channel (continuous) anode flow field plate, and (I) the cathode flow field plate illustrated in FIG. 9 formed of a graphite foil laminate and a 2 channel (continuous) anode flow field plate.

FIG. 13 is a side sectional view of a fuel cell incorporating a fluid flow field plate having discontinuous flow channels showing schematically the flow of reactant through a section of the fuel cell.

Detailed Description Of The Preferred Embodiments

Turning first to FIG. 1, a fuel cell stack assembly 10 includes an electrochemically active section 26 and optionally includes a humidification

section 28. Stack assembly 10 is a modular plate and frame design, and includes a compression end plate 16 and a fluid end plate 18. An optional pneumatic piston 17, positioned within compression end plate 16, applies uniform pressure to the assembly to promote sealing. Bus plates 22 and 24 located on opposite ends of active section 26 provide the negative and positive contacts, respectively, for the electrical path directing current generated by the assembly to an external electrical load (not shown). Tie rods 20 extend between end plates 16 and 18 to retain and secure stack assembly 10 in its assembled state with fastening nuts 21.

Active section 26 includes, in addition to bus plates 22 and 24, a plurality of fuel cell repeating units 12. Each repeating unit 12 consists of a membrane electrode assembly, an anode fluid flow field plate, a cathode fluid flow field plate (or alternatively anode and cathode separator layers if the anode and cathode reactant flow channels are formed in the surfaces of the electrode material) and optionally a cooling jacket, as described in more detail below. In the assembly illustrated in FIG. 1, the repeating units 12 are electrically coupled in series by virtue of the contact between the electrically conductive layers which form the flow field plates (or the separator layers) and the cooling jackets.

Optional humidification section 28 includes a plurality of humidification assemblies 14, each assembly 14 consisting of fuel or oxidant reactant flow field plate, a water flow field plate, and a water transport membrane interposed between the

reactant flow field plate and the water flow field plate. When present, humidification section 28 imparts water to the fuel and oxidant streams fed to active section 26, thereby preventing the membranes within the active section from drying out.

FIG. 2 illustrates a fuel cell 30, which includes a membrane electrode assembly 32 interposed between rigid flow field plates 34 and 36. Membrane electrode assembly 32 consists of an ion exchange membrane 42 interposed between two electrodes, namely, anode 44 and cathode 46. Anode 44 and cathode 46 are typically formed of porous electrically conductive sheet material, preferably carbon fiber paper, and have planar major surfaces. Electrodes 44 and 46 have a thin layer of catalyst material disposed on their surfaces at the interface with membrane 42 to render them electrochemically active.

As shown in FIG. 2, anode flow field plate 34 has at least one open faced channel 34a engraved, milled or molded in its surface facing membrane 42. Similarly, cathode flow field plate 36 has at least one open faced channel 36a engraved, milled or molded in its surface facing membrane 42. When assembled against the cooperating surfaces of electrodes 44 and 46, channels 34a and 36a form the reactant flow field passages for the fuel and oxidant, respectively.

Turning now to FIG. 3, a fuel cell 50 employs a membrane electrode assembly 50 having integral reactant fluid flow channels. Fuel cell 50 includes membrane electrode assembly 52 interposed between lightweight separator layers 54 and 56,

which are substantially impermeable to the flow of reactant fluid therethrough. Membrane electrode assembly 52 consists of an ion exchange membrane 62 interposed between two electrodes, namely, anode 64 and cathode 66. Anode 64 and cathode 66 are formed of porous electrically conductive sheet material, preferably carbon fiber paper. Electrodes 64 and 66 have a thin layer of catalyst material disposed on their surfaces at the interface with membrane 62 to render them electrochemically active.

As shown in FIG. 3, anode 64 has at least one open faced channel 64a formed in its surface facing away from membrane 62. Similarly, cathode 66 has at least one open faced channel 66a formed in its surface facing away from membrane 62. When assembled against the cooperating surfaces of separator layers 54 and 56, channels 64a and 66a form the reactant flow field passages for the fuel and oxidant, respectively. U.S. Patent Application Serial No. 07/759,463 filed September 13, 1991 describes in more detail a lightweight fuel cell membrane electrode assembly with integral reactant flow passages, and is incorporated by reference herein.

A prior art fluid flow field plate 110 having a single continuous reactant flow channel, described in Watkins U.S. Patent No. 4,988,583, is shown in FIG. 4. Major plate surface 115 has formed therein, typically by numerically controlled machining, stamping or molding, a single continuous fluid flow channel 122. Channel 122 has a fluid inlet 124 at one end and a fluid outlet 126 at the other end. Fluid inlet 124 is directly connected to a fluid supply opening or manifold 125 formed in

plate 112. Fluid outlet 126 is directly connected to a fluid exhaust opening or manifold 127 formed in plate 112. Fluid opening 126 is connected to a source of fuel (not shown) in the case of the anode flow field plate or a source of oxidant (not shown) for the cathode flow field plate. Channel 122 traverses in a plurality of passes a major central area of plate 112, which in turn generally corresponds to the electrocatalytically active region of the anode or cathode to which it is adjacent when assembled.

FIG. 5 shows a cross sectional view of the channel 122 of fluid flow field plate 110 in FIG. 4. Channel 122 has a configuration that is typical of machined open face channels, namely, it is defined by a substantially flat base 129 and opposing side walls 130 which diverge outwardly toward the open face 123 of channel 122. The illustrated cross sectional configuration of channel 122 is designed to minimize tool wear. Channel 122 is preferably of uniform depth throughout its length. A series of lands 132 is defined between the passes of channel 122. When assembled, the lands 132 between channels 122 are in contact with the electrode surface adjacent thereto, so that each flow field plate also functions as a current collector.

A prior art fluid flow field plate 140 having multiple continuous reactant flow channels, described in Watkins U.S. Patent No. 5,108,849, is shown in FIG. 6. Major surface 142 has formed therein a plurality of flow field channels, several of which are designated by the numeral 144. Channels 144 define a generally serpentine path

between fluid supply opening or manifold 145 and fluid exhaust opening or manifold 147. Each channel 144 has an inlet end 146 and an outlet end 148 directly connected to the respective fluid supply openings 145 and fluid exhaust openings 147. Plate 140, which contains ten (10) individual serpentine channels 144, has been found to operate effectively in a fuel cell adjacent the cathode, and is sometimes referred to as a 10-pass cathode flow field plate. A greater or lesser number of channels 144 could be incorporated in the plate, such as, for example, in the case of a 2-pass flow field plate which has been found to operate effectively adjacent the anode, and is sometimes referred to as a 2-pass anode flow field plate.

FIG. 7 shows a first embodiment of a fluid flow field plate 160 having discontinuous fluid flow channels. Plate 160 has a fluid inlet opening 162 in fluid communication with an inlet header 164 formed in the surface 161 of plate 160. Inlet channels 166 extend from inlet header 164 toward the central region of plate, which is adjacent the electrocatalytically active region of the electrode with which plate 160 is associated. Plate 160 also has a fluid outlet opening 168 in fluid communication with an outlet header 170 formed in the surface of plate 160. Outlet channels 172 extend from outlet header 170 toward the central region of the plate. As illustrated in FIG. 7, inlet channels 166 and outlet channels 172 are interdigitated, so that a pressurized fluid stream entering through opening 162 will be directed by inlet header 164 to inlet channels 166. At that point, the fluid stream will be forced through the

interstices of the adjacent porous electrode material (not shown) on either side of the inlet channel 166 to one of the nearby outlet channels 172. From there, the fluid stream will flow through outlet header 170 to fluid outlet opening 168, where it is discharged from the flow field plate 160.

FIG. 8 shows a second embodiment of a fluid flow field plate 180 having eleven (11) discontinuous, interdigitated fluid flow channels. Plate 180 has a fluid inlet 182 formed in the surface 181 of plate 180. Inlet channels 186 extend from inlet 182 toward the central region of plate, which is adjacent the electrocatalytically active region of the electrode with which plate 180 is associated. Plate 180 also has a fluid outlet 188 formed in the surface 181 of plate 180. Outlet channels 192 extend from outlet 188 toward the central region of the plate. As illustrated in FIG. 8, inlet channels 186 and outlet channels 192 are interdigitated, so that a pressurized fluid stream entering through opening 182 will be directed to inlet channels 186. At that point, the fluid stream will be forced through the interstices of the adjacent porous electrode material (not shown) on either side of each inlet channel 186 to one of the nearby outlet channels 192. From there, the fluid stream will flow through outlet 188, where it is discharged from the flow field plate 180.

As shown in FIG. 8, plate 180 contains eleven (11) discontinuous fluid flow channels, five (5) channels of which are inlet channels extending from the inlet and six (6) channels of which are outlet

channels extending from the outlet. Each of the inlet channels is preferably disposed between a pair of outlet channels so that the fluid stream from the inlet channels is uniformly directed from either side of the inlet channels to one of the neighboring outlet channels.

FIG. 8 also illustrates the location of a sealant or gasketing material 194 which contacts surface 181 and circumscribes the central area of plate 180. Sealant or gasketing material 194 isolates and defines within it the electrocatalytically active region of the fuel cell adjacent plate 180. Plate 180 also has other openings 196 formed therein, which serve as the manifolds for other reactant and coolant streams within the fuel cell.

FIG. 9 shows a third embodiment of a fluid flow field plate 210 having seven (7) discontinuous fluid flow channels. Plate 210 has a fluid inlet 212 formed in the surface 211 of plate 210. Inlet channels 216 extend from inlet 212 toward the central region of plate, which is adjacent the electrocatalytically active region of the electrode (not shown) with which plate 210 is associated. Plate 210 also has a fluid outlet 218 formed in the surface 211 of plate 210. Outlet channels 222 extend from outlet 218 toward the central region of the plate. As illustrated in FIG. 8, inlet channels 216 and outlet channels 222 are interdigitated, so that a pressurized fluid stream entering through opening 212 will be directed to inlet channels 216. At that point, the fluid stream will be forced through the interstices of the adjacent porous electrode material (not shown)

on either side of each inlet channel 216 to one of the nearby outlet channels 222. From there, the fluid stream will flow through outlet 218, where it is discharged from the flow field plate 210 and exhausted from the fuel cell.

As shown in FIG. 9, plate 210 contains seven (7) discontinuous fluid flow channels, three (3) channels of which are inlet channels extending from the inlet and four (4) channels of which are outlet channels extending from the outlet. As with the flow channels of plate 180 in FIG. 8, each of the inlet channels of plate 210 is preferably disposed between a pair of outlet channels so that the fluid stream from the inlet channels is uniformly directed from either side of the inlet channels to each of the neighboring outlet channels.

FIG. 9 also illustrates the location of sealant or gasketing material 224 which contacts surface 211 and circumscribes the central area of plate 210. Sealant or gasketing material 224 isolates and defines within it the electrocatalytically active region of the fuel cell adjacent the central area of plate 210. In the central area of plate 210 circumscribed by sealant or gasketing material 224, the inlet and outlet channels 216 and 222 are parallel and do not converge toward the respective inlet and outlet openings until the channels exit the electrocatalytically active region. Plate 180 also has other openings 226 formed therein, which serve as the manifolds for other reactant and coolant streams within the fuel cell.

While the fluid flow field plates illustrated in FIGS. 4 and 6-9, contain fluid manifolds formed

within the plates, it will be understood that the other means for introducing fluids to and discharging fluids from the surface of the plates are possible. For example, external manifolds may be preferred in some instances to introduce fluids through an inlet (or inlets) located along an edge (or edges) of the plate and to discharge fluids from the plate surface through an outlet (or outlets) located along another edge (or edges) of the plate. The discontinuous flow channels described and claimed herein extend to fuel cells employing such other external manifold designs.

FIG. 10 is a plot of cell voltage as a function of current density for a fuel cell operated at two different reactant inlet pressures and cathode flow field plate configurations. In each of plots A-D, a 2-pass anode flow field plate was employed, along with the following operating conditions: 2.0/1.5 air/H_2 stoichiometry, temperature = 75°C, Dow experimental cation exchange membrane. Plot A shows the baseline performance at 30/30 psig (air/H_2) of a fuel cell employing the 10-pass continuous channel cathode flow field plate illustrated in FIG. 6. Plot B shows the performance at 30/30 psig (air/H_2) of a fuel cell employing the 11 channel (discontinuous) cathode flow field plate illustrated in FIG. 8. Plot C shows the baseline performance at 60/60 psig (air/H_2) of a fuel cell employing the 10-pass continuous channel cathode flow field plate illustrated in FIG. 6. Plot D shows the performance at 60/60 psig (air/H_2) of a fuel cell employing the 11 channel (discontinuous) cathode flow field plate illustrated in FIG. 8. FIG. 10

shows that the performance of a fuel cell employing a cathode flow field plate having discontinuous, interdigitated flow channels, is superior to that of a fuel cell employing a cathode flow field plate having continuous, serpentine flow channels, all other components and conditions being essentially equal.

The following Table 1 summarizes the performance results, including voltage at 500 amps per square foot (ASF) of electrocatalytically active area, for a fuel cell employing anode and cathode flow field plates having 11 discontinuous, interdigitated ("Int.") flow channels as illustrated in FIG. 8. Standard ("Std.") anode and cathode flow fields refer to the continuous, serpentine 2-pass (anode) and 10-pass (cathode) flow field plates. The Dow experimental cation exchange membrane, 70°C cell temperature, and 2.0/1.5 air/H_2 stoichiometry were employed in each of the experiments reported in Table 1.

TABLE 1

Flow Field Type	Pressure (psig)	Pressure Drop (psi)	Voltage at 500 ASF
Std. Anode	30	0.9	0.728
Std. Cathode	30	0.5	
Std. Anode	30	0.9	0.733
Int. Cathode	30	2.6	
Int. Anode	30	0.4	0.733
Std. Cathode	30	0.5	
Int. Anode	30	0.4	0.716
Int. Cathode	30	2.6	
Std. Anode	60	0.7	0.752
Std. Cathode	60	0.4	
Std. Anode	60	0.7	0.763
Int. Cathode	30	2.1	
Int. Anode	60	0.4	0.751
Std. Cathode	60	0.4	
Int. Anode	30	0.4	0.747
Int. Cathode	30	2.1	

Thus, the incorporation of discontinuous, interdigitated flow channels in the cathode flow field plate results in improved fuel cell performance compared to a standard (continuous) flow channels. The incorporation of discontinuous

flow channels in the anode flow field plate results in either slightly improved (at 30/30 psig) or slightly deteriorated (at 60/60 psig) performance compared to the standard (continuous) flow channel configuration.

FIG. 11 is a plot of cell voltage as a function of current density for a fuel cell at 60/60 psig (air/H_2) with a standard (continuous) and two discontinuous, interdigitated flow field configurations. In each of plots E-G, a 2-pass anode flow field plate was employed, along with the following operating conditions: 2.0/1.5 air/H_2 stoichiometry, temperature = 75°C, Dow experimental cation exchange membrane. Plot E shows the baseline performance at 60/60 psig (air/H_2) of a fuel cell employing the 10-pass continuous channel cathode flow field plate illustrated in FIG. 6. Plot F shows the performance at 60/60 psig (air/H_2) of a fuel cell employing the 11 channel (discontinuous) cathode flow field plate illustrated in FIG. 8. Plot G shows the performance at 60/60 psig (air/H_2) of a fuel cell employing the 7 channel (discontinuous) cathode flow field plate illustrated in FIG. 9, in which the inlet and outlet channels are parallel and do not converge toward the respective inlet and outlet openings until the channels are outside the central area of the plate adjacent the electrocatalytically active region of the fuel cell. FIG. 11 shows that the performance of a fuel cell employing the 7 discontinuous, non-converging channel cathode flow field plate is superior to that of a fuel cell employing a cathode flow field plate having 11 discontinuous, interdigitated flow channels, which

is in turn superior to the performance of a fuel cell employing a cathode flow field plate having continuous, serpentine flow channels, all other components and conditions being essentially equal.

The fluid flow field plates described herein are formed of a suitable electrically conductive material. A rigid, non-porous graphite or impregnated carbon plate has been found useful for fuel cell applications. A carbonaceous material is preferred because it is chemically inert in the fuel cell environment and it is relatively inexpensive. Other suitable electrically conductive materials could be used to form the flow field plates herein, including corrosion resistant metals such as niobium, somewhat corrosive resistant materials such as magnesium or copper, particularly when plated with noble metals such as gold or platinum to render them unreactive, and composite materials composed of a corrosive resistant metal powder, a base metal powder plated with the corrosive resistant metal, and/or other chemically inert electrically conductive powders, such as graphite and boron carbide, bonded together with a suitable binder to produce a rigid, electrically conductive plate. Suitable polymeric binders include thermoplastic resins suitable for injection molding, such as polyvinylidene fluoride (trade name KYNAR) commercially available from Penwalt Corporation. Typical composites include about 70-90% by weight of high purity graphite powder and about 10-30% by weight of polyvinylidene fluoride. As indicated below, the flow field plates described herein can also be formed as a laminated assembly of graphite foil layers.

FIG. 12 is a plot of cell voltage as a function of current density for a fuel cell at 30/30 psig (air/H_2) with a 7 discontinuous, non-converging channel cathode flow field plate formed of two different graphite materials. In each of plots H and I, a 2-pass anode flow field plate was employed, along with the following operating conditions: 2.0/1.5 air/H_2 stoichiometry, temperature = 75°C, Dow experimental cation exchange membrane. Plot H shows the performance of a fuel cell employing the cathode flow field plate illustrated in FIG. 9 formed of solid graphite. Plot I shows the performance of a fuel cell employing the cathode flow field plate illustrated in FIG. 9 formed of a graphite foil laminate (commercially available from Union Carbide Corporation under the trade name GRAFOIL). FIG. 12 shows that the performance of the solid graphite flow field plate was superior to the graphite foil laminate. However, the ease of manufacture of laminated flow field plates as a stacked, consolidated array of graphite foil layers having the flow field pattern stamped therefrom renders the configuration of plot I economically viable even though its performance is slightly less favorable than the solid graphite counterpart in plot H.

FIG. 13 is side sectional view of a fuel cell 310 incorporating a flow field plate having discontinuous flow channels showing schematically the flow of reactant through a section of the fuel cell. Fuel cell 310 includes an ion exchange membrane 312 interposed between an anode 314 and a cathode 316. Cathode 316 is formed of a layer of

porous, electrically conductive sheet material. Cathode flow field plate 318 has an inlet channel 320 and an outlet channel 322 formed therein. As shown schematically in FIG. 13, reactant stream 322 flows from inlet channel 320 into the interstices of cathode 316 and then to outlet channel 322. The discontinuity between inlet channel 320 and outlet channel 322 urges the pressurized reactant stream to flow within the porous internal structure of cathode 316, resulting in more proximate access of reactant to the electrocatalytically active region at the interface of cathode 316 and membrane 312, as well as more effective removal of water from the membrane/electrode interface by reactant stream 322.

The discontinuous flow field channel configurations illustrated in FIGS. 7-9 and described above can also be formed in the surface of the electrode, in the manner illustrated in FIG. 3. In this integrated flow channel embodiment, the graphite flow field plates are replaced with thinner, separator plates, preferably formed of graphite foil, that are substantially impermeable to the flow of reactant therethrough. In the electrodes having integrated discontinuous flow fields formed therein, the discontinuity between the inlet channels and the outlet channels urges the reactant stream to flow within the interstices of the electrode in a manner analogous to that achieved with the graphite flow field plates having discontinuous flow channels illustrated in FIGS. 7-9.

The employment of discontinuous flow channels, as described herein, has several advantages:

1. Improved performance, particularly at higher reactant inlet pressures, resulting from (a) the increased partial pressure of reactant gases in the electrochemically active region of the fuel cell at the membrane/electrode interface, (b) more effective water removal due to better access of the reactant stream to the electrocatalytically active region at the membrane/electrode interface, (c) more uniform current density due to more even distribution of the reactant stream across the electrocatalytically active area of the fuel cell and the avoidance of water pooling in the flow channels, and (d) lower flow field plate/electrode contact resistance due to the use of a decreased amount of the flow field plate surface to accommodate the flow channels.
2. Improved fuel cell lifetime resulting from (a) the ability to reduce the compressive load on the electrodes due to decreased contact resistance between the flow field plates and the electrodes, and (b) more uniform reactant gas relative humidity due to the more uniform distribution of reactant gas compared to the continuous, serpentine flow channel design.
3. Reduced manufacturing costs resulting from (a) the ability to reduce the amount of graphite plate milling required for continuous channels and to relax the

tolerances required for the channel dimensions, (b) a wider range of materials and fabrication techniques permitted with the discontinuous flow channel design, such as stamping of flow field stencils, to be employed, particularly the use of thinner electrically conductive sheet materials, as the discontinuous channels do not require the thickness and rigidity of the electrically conductive plates in which continuous, serpentine flow channels are formed, and (3) the ability to employ a stenciled graphite foil laminate, thereby reducing the weight (and cost) associated with rigid graphite flow field plates.

Regarding manufacturability, the sizing of the channels is a principal determinant of the flow characteristics (pressure and turbulence) in continuous flow channel designs. Slight deviations in the dimensions or configuration of the continuous flow channels can have a significant effect on the pressure drop and turbulence. In the discontinuous design, the reactant flow characteristics are primarily determined by the porosity of the electrode, and higher (less stringent) tolerances can be accepted in the flow channels because the effect of the porous electrode material on the flow of reactant therethrough is much greater than the effect of channel size or configuration.

The discontinuous flow channel design also permits the pressure drop of the reactants to be controlled through the use of different electrode

porosities. In this regard, increasing the porosity of the electrode material between the inlet and outlet channels will result in a lowering of the pressure drop. Conversely, decreasing the porosity of the electrode material will increase the pressure drop. Similarly, increasing the distance between the inlet channels and outlet channels will increase the pressure drop because of the increased amount of porous (but nevertheless flow resistant) material through which the reactant stream must pass. The discontinuous flow channel designs therefore permit the porosity of the electrode material to be employed as a controlling factor for the pressure drop of the reactant stream between the inlet and the outlet of the fuel cell.

While particular elements, embodiments and applications of the present invention have been shown and described, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. It is therefore contemplated by the appended claims to cover such modifications as incorporate those features which come within the spirit and scope of the invention.

What is claimed is:

1. A fluid flow field plate for an electrochemical fuel cell, said plate having an inlet for introducing fluid to a major surface thereof and an outlet for discharging fluid from said major surface, said major surface having formed therein at least one inlet channel extending from said inlet and at least one outlet channel extending from said outlet, wherein said at least one inlet channel is discontinuous with respect to said at least one outlet channel.

2. The fluid flow field plate of claim 1 wherein said plate formed of electrically conductive material.

3. The fluid flow field plate of claim 1 wherein said at least one inlet channel comprises an inlet header channel extending from said fluid inlet and a plurality of inlet branch channels extending from said inlet header channel.

4. The fluid flow field plate of claim 1 wherein said at least one outlet channel comprises an outlet header channel extending from said fluid outlet and a plurality of outlet branch channels extending from said outlet header channel.

5. The fluid flow field plate of claim 1 wherein said at least one outlet channel comprises a plurality of separate outlet channels, each pair of adjacent outlet channels having an inlet channel disposed therebetween along a substantial portion

thereof.

6. The fluid flow field plate of claim 5 wherein said at least one outlet channel comprises at least three separate outlet channels and wherein each inlet channel disposed between each pair of adjacent outlet channels is separate with respect to the remainder of said inlet channels.

7. An electrode assembly for an electrochemical fuel cell, said assembly comprising:

an inlet for introducing a pressurized fluid reactant stream to said assembly;

an outlet for discharging said fluid reactant stream from said assembly;

a layer of electrically conductive material permeable to said fluid reactant, said fluid permeable layer having a major surface;

a layer of electrically conductive material substantially impermeable to said fluid reactant, said fluid impermeable layer having formed in a major surface thereof at least one inlet channel extending from said inlet and at least one outlet channel extending from said outlet, wherein said at least one inlet channel is discontinuous with respect to said at least one outlet channel, said fluid permeable and fluid impermeable layers contacting each other at their respective major surfaces;

whereby said fluid reactant is urged through the interstices of said fluid

permeable layer between said at least one inlet channel and said at least one outlet channel.

8. The electrode assembly of claim 7 wherein said at least one inlet channel comprises an inlet header channel extending from said inlet and a plurality of inlet branch channels extending from said inlet header channel.

9. The electrode assembly of claim 7 wherein said at least one outlet channel comprises an outlet header channel extending from said outlet and a plurality of outlet branch channels extending from said outlet header channel.

10. The electrode assembly of claim 7 wherein said at least one outlet channel comprises a plurality of separate outlet channels, each pair of adjacent outlet channels having an inlet channel disposed therebetween along a substantial portion thereof.

11. The electrode assembly of claim 10 wherein said at least one outlet channel comprises at least three separate outlet channels and wherein each inlet channel disposed between each pair of adjacent outlet channels is separate with respect to the remainder of said inlet channels.

12. The electrode assembly of claim 11 wherein said fluid permeable layer has a catalyst associated therewith to render a region of said electrode assembly electrocatalytically active and

wherein said inlet channels and said outlet channels are substantially parallel along the portions of said channels adjacent said active region.

13. An electrode assembly for an electrochemical fuel cell, said assembly comprising:

an inlet for introducing a pressurized fluid reactant stream to said assembly;

an outlet for discharging said fluid reactant stream from said assembly;

a layer of electrically conductive material permeable to said fluid reactant, said fluid permeable layer having formed in a major surface thereof at least one inlet channel extending from said inlet and at least one outlet channel extending from said outlet, wherein said at least one inlet channel is discontinuous with respect to said at least one outlet channel;

a layer of electrically conductive material substantially impermeable to said fluid reactant, said fluid impermeable layer having a major surface, said fluid permeable and fluid impermeable layers contacting each other at their respective major surfaces;

whereby said fluid reactant is urged through the interstices of said fluid permeable layer between said at least one inlet channel and said at least one outlet channel.

14. The electrode assembly of claim 13 wherein said at least one inlet channel comprises an inlet header channel extending from said inlet and a plurality of inlet branch channels extending from said inlet header channel.

15. The electrode assembly of claim 13 wherein said at least one outlet channel comprises an outlet header channel extending from said outlet and a plurality of outlet branch channels extending from said outlet header channel.

16. The electrode assembly of claim 13 wherein said at least one outlet channel comprises a plurality of separate outlet channels, each pair of adjacent outlet channels having an inlet channel disposed therebetween along a substantial portion thereof.

17. The electrode assembly of claim 16 wherein said at least one outlet channel comprises at least three separate outlet channels and wherein each inlet channel disposed between each pair of adjacent outlet channels is separate with respect to the remainder of said inlet channels.

18. The electrode assembly of claim 17 wherein said fluid permeable layer has a catalyst associated therewith to render a region of said electrode assembly electrocatalytically active and wherein said inlet channels and said outlet channels are substantially parallel along the portions of said channels adjacent said active region.

19. An electrochemical fuel cell comprising:

(a) an anode assembly having a catalyst associated therewith to render a region of said anode electrocatalytically active wherein cations are produced from a fuel;

(b) a cathode assembly comprising:

an oxidant inlet for introducing a pressurized fluid oxidant stream to said cathode assembly;

an oxidant outlet for discharging said fluid oxidant stream from said cathode assembly;

a layer of electrically conductive material permeable to said oxidant, said oxidant permeable layer having a major surface, said oxidant permeable layer having a catalyst associated therewith to render a region of said cathode electrocatalytically active wherein an electrochemical reaction between said cations and said oxidant is promoted;

a layer of electrically conductive material substantially impermeable to said oxidant, said oxidant impermeable layer having formed in a major surface thereof at least one oxidant inlet channel extending from said oxidant inlet and at least one oxidant outlet channel extending from said oxidant outlet, wherein said at least one oxidant inlet channel is discontinuous with respect to said at least one oxidant outlet channel, said oxidant permeable and oxidant impermeable layers contacting each other

at their respective major surfaces;

whereby said oxidant is urged through the interstices of said oxidant permeable layer between said at least one oxidant inlet channel and said at least one oxidant outlet channel;

(c) a solid polymer ion exchange membrane disposed between said anode assembly and said cathode assembly, said membrane facilitating the migration of cations from said anode assembly to said cathode assembly and isolating said fuel from said fluid oxidant stream; and

(d) an electrical path for conducting electrons formed at said anode assembly to said cathode assembly.

20. The electrochemical fuel cell of claim 19 wherein said at least one oxidant inlet channel comprises an oxidant inlet header channel extending from said oxidant inlet and a plurality of inlet branch channels extending from said inlet header channel.

21. The electrochemical fuel cell of claim 19 wherein said at least one oxidant outlet channel comprises an oxidant outlet header channel extending from said oxidant outlet and a plurality of oxidant outlet branch channels extending from said oxidant outlet header channel.

22. The electrochemical fuel cell of claim 19 wherein said at least one oxidant outlet channel comprises a plurality of separate oxidant outlet

channels, each pair of adjacent oxidant outlet channels having an oxidant inlet channel disposed therebetween along a substantial portion thereof.

23. The electrochemical fuel cell of claim 22 wherein said at least one oxidant outlet channel comprises at least three separate oxidant outlet channels and wherein each oxidant inlet channel disposed between each pair of adjacent oxidant outlet channels is separate with respect to the remainder of said oxidant inlet channels.

24. The electrochemical fuel cell of claim 23 wherein said oxidant inlet channels and said oxidant outlet channels are substantially parallel along the portions of said oxidant channels adjacent said cathode active region.

25. The electrochemical fuel cell of claim 19 wherein said anode assembly further comprises:

a fuel inlet for introducing a pressurized fluid fuel stream to said anode assembly;

a fuel outlet for discharging said fuel stream from said assembly;

a layer of electrically conductive material permeable to said fuel, said fuel permeable layer having a major surface,

a layer of electrically conductive material substantially impermeable to said fuel, said fuel impermeable layer having a major surface, said fuel permeable and fuel impermeable layers contacting each other at their respective major surfaces;

whereby said fuel is urged through the interstices of said fuel permeable layer between said at least one fuel inlet channel and said at least one fuel outlet channel.

26. The electrochemical fuel cell of claim 25 wherein said at least one fuel inlet channel comprises a fuel inlet header channel extending from said fuel inlet and a plurality of fuel inlet branch channels extending from said fuel inlet header channel.

27. The electrochemical fuel cell of claim 25 wherein said at least one fuel outlet channel comprises a fuel outlet header channel extending from said fuel outlet and a plurality of fuel outlet branch channels extending from said fuel outlet header channel.

28. The electrochemical fuel cell of claim 25 wherein said at least one fuel outlet channel comprises a plurality of separate fuel outlet channels, each pair of adjacent fuel outlet channels having a fuel inlet channel disposed therebetween along a substantial portion thereof.

29. The electrochemical fuel cell of claim 28 wherein said at least one fuel outlet channel comprises at least three separate fuel outlet channels and wherein each fuel inlet channel disposed between each pair of adjacent fuel outlet channels is separate with respect to the remainder of said fuel inlet channels.

30. The electrochemical fuel cell of claim 29 wherein said fuel inlet channels and said fuel outlet channels are substantially parallel along the portions of said channels adjacent said anode active region.

31. An electrochemical fuel cell comprising:

(a) an anode assembly having a catalyst associated therewith to render a region of said anode electrocatalytically active wherein cations are produced from a fuel;

(b) a cathode assembly comprising:

an oxidant inlet for introducing a pressurized fluid oxidant stream to said cathode assembly;

an oxidant outlet for discharging said fluid oxidant stream from said cathode assembly;

a layer of electrically conductive material permeable to said oxidant, said oxidant permeable layer having a catalyst associated therewith to render a region of said cathode electrocatalytically active wherein an electrochemical reaction between said cations and said oxidant is promoted, said oxidant permeable layer having formed in a major surface thereof at least one oxidant inlet channel extending from said oxidant inlet and at least one oxidant outlet channel extending from said oxidant outlet, wherein said at least one oxidant inlet channel is discontinuous with respect to said at least one oxidant

outlet channel;

a layer of electrically conductive material substantially impermeable to said oxidant, said oxidant impermeable layer having a major surface, said oxidant permeable and oxidant impermeable layers contacting each other at their respective major surfaces;

whereby said oxidant is urged through the interstices of said oxidant permeable layer between said at least one oxidant inlet channel and said at least one oxidant outlet channel;

(c) a solid polymer ion exchange membrane disposed between said anode assembly and said cathode assembly, said membrane facilitating the migration of cations from said anode assembly to said cathode assembly and isolating said fuel from said fluid oxidant stream; and

(d) an electrical path for conducting electrons formed at said anode assembly to said cathode assembly.

32. The electrochemical fuel cell of claim 31 wherein said at least one oxidant inlet channel comprises an oxidant inlet header channel extending from said oxidant inlet and a plurality of inlet branch channels extending from said inlet header channel.

33. The electrochemical fuel cell of claim 31 wherein said at least one oxidant outlet channel comprises an oxidant outlet header channel

extending from said oxidant outlet and a plurality of oxidant outlet branch channels extending from said oxidant outlet header channel.

34. The electrochemical fuel cell of claim 31 wherein said at least one oxidant outlet channel comprises a plurality of separate oxidant outlet channels, each pair of adjacent oxidant outlet channels having an oxidant inlet channel disposed therebetween along a substantial portion thereof.

35. The electrochemical fuel cell of claim 34 wherein said at least one oxidant outlet channel comprises at least three separate oxidant outlet channels and wherein each oxidant inlet channel disposed between each pair of adjacent oxidant outlet channels is separate with respect to the remainder of said oxidant inlet channels.

36. The electrochemical fuel cell of claim 35 wherein said oxidant inlet channels and said oxidant outlet channels are substantially parallel along the portions of said oxidant channels adjacent said cathode active region.

37. The electrochemical fuel cell of claim 31 wherein said anode assembly further comprises:

a fuel inlet for introducing a pressurized fluid fuel stream to said anode assembly;

a fuel outlet for discharging said fluid fuel stream from said assembly;

a layer of electrically conductive material permeable to said fuel, said fuel

permeable layer having formed in a major surface thereof at least one fuel inlet channel extending from said fuel inlet and at least one fuel outlet channel extending from said fuel outlet, wherein said at least one fuel inlet channel is discontinuous with respect to said at least one fuel outlet channel;

a layer of electrically conductive material substantially impermeable to said fuel, said fuel impermeable layer having a major surface, said fuel permeable and fuel impermeable layers contacting each other at their respective major surfaces;

whereby said fuel is urged through the interstices of said fuel permeable layer between said at least one fuel inlet channel and said at least one fuel outlet channel.

38. The electrochemical fuel cell of claim 37 wherein said at least one fuel inlet channel comprises a fuel inlet header channel extending from said fuel inlet and a plurality of fuel inlet branch channels extending from said fuel inlet header channel.

39. The electrochemical fuel cell of claim 37 wherein said at least one fuel outlet channel comprises a fuel outlet header channel extending from said fuel outlet and a plurality of fuel outlet branch channels extending from said fuel outlet header channel.

40. The electrochemical fuel cell of claim 37 wherein said at least one fuel outlet channel comprises a plurality of separate fuel outlet channels, each pair of adjacent fuel outlet channels having a fuel inlet channel disposed therebetween along a substantial portion thereof.

41. The electrochemical fuel cell of claim 40 wherein said at least one fuel outlet channel comprises at least three separate fuel outlet channels and wherein each fuel inlet channel disposed between each pair of adjacent fuel outlet channels is separate with respect to the remainder of said fuel inlet channels.

42. The electrochemical fuel cell of claim 41 wherein said fuel inlet channels and said fuel outlet channels are substantially parallel along the portions of said channels adjacent said anode active region.

Fig. 1

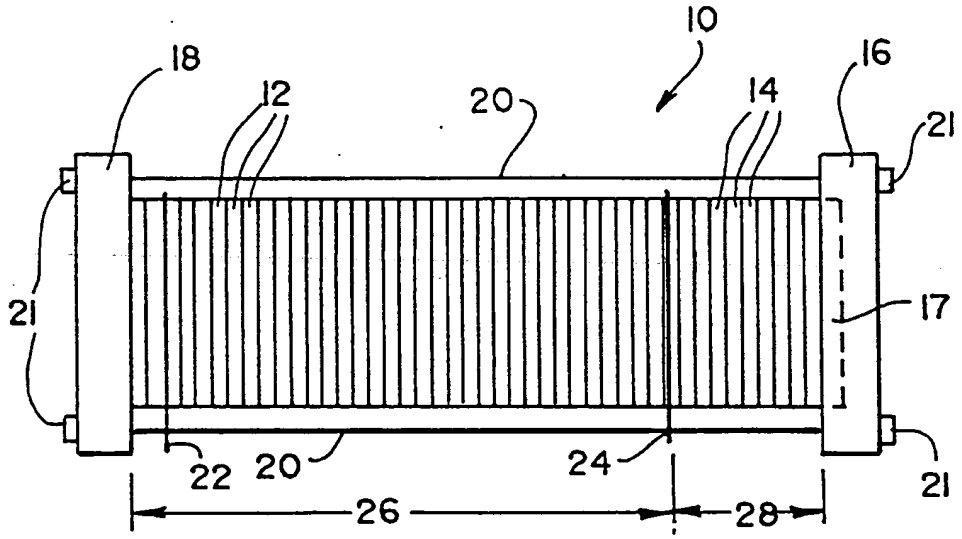

Fig. 2

Prior Art

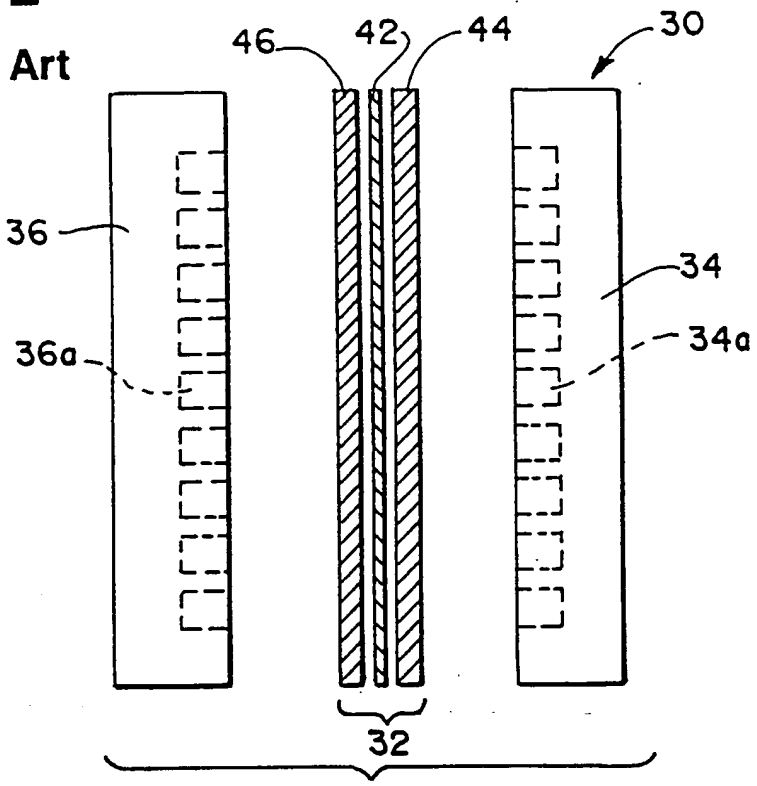

Fig. 3

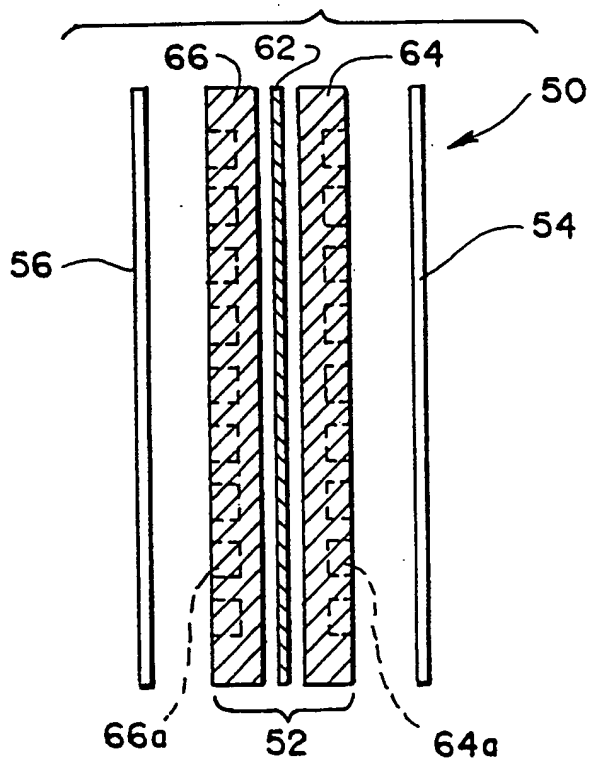

Fig. 4

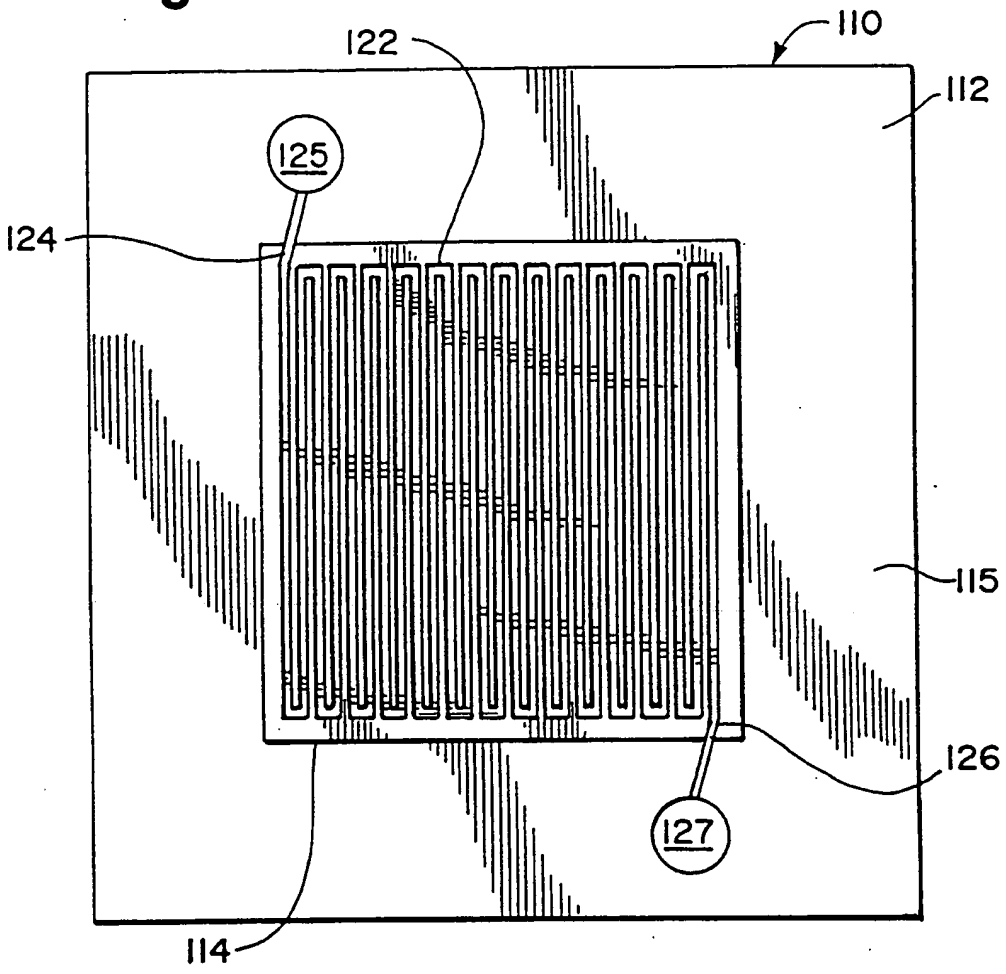

Fig. 5

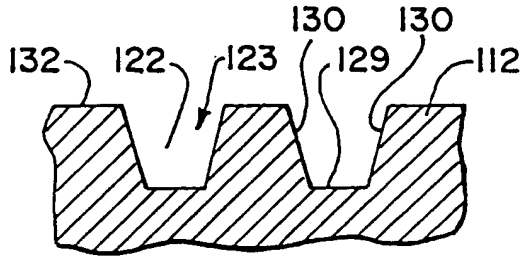

Fig. 6

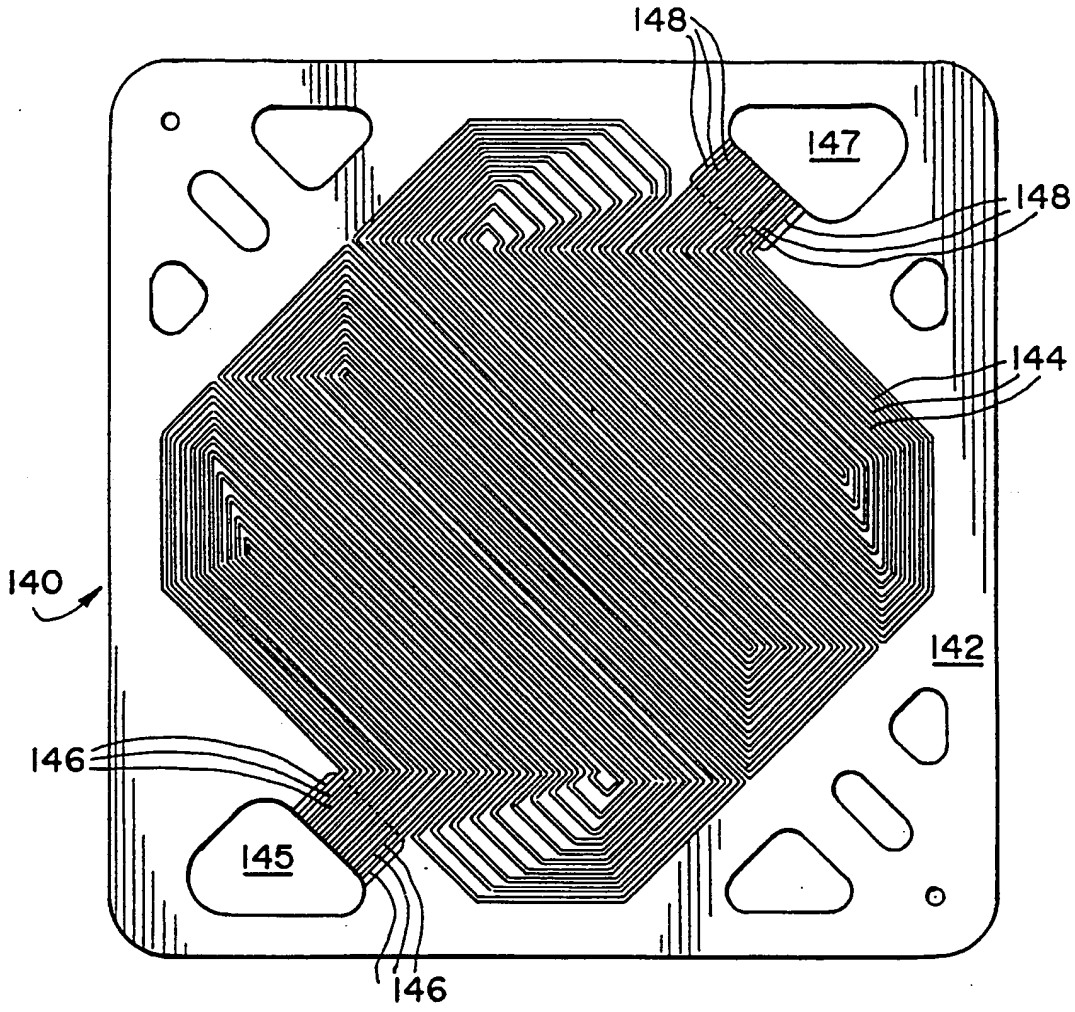
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Fig. 7

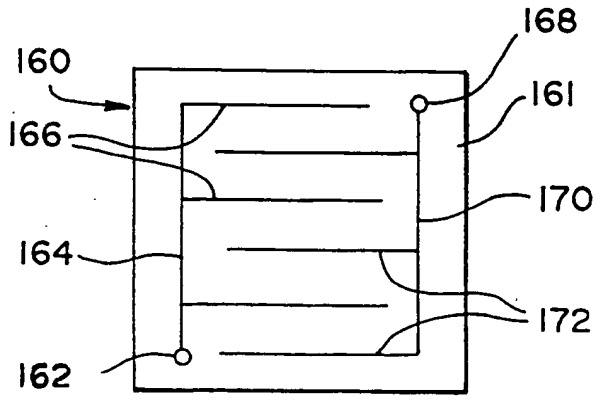
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Fig. 8

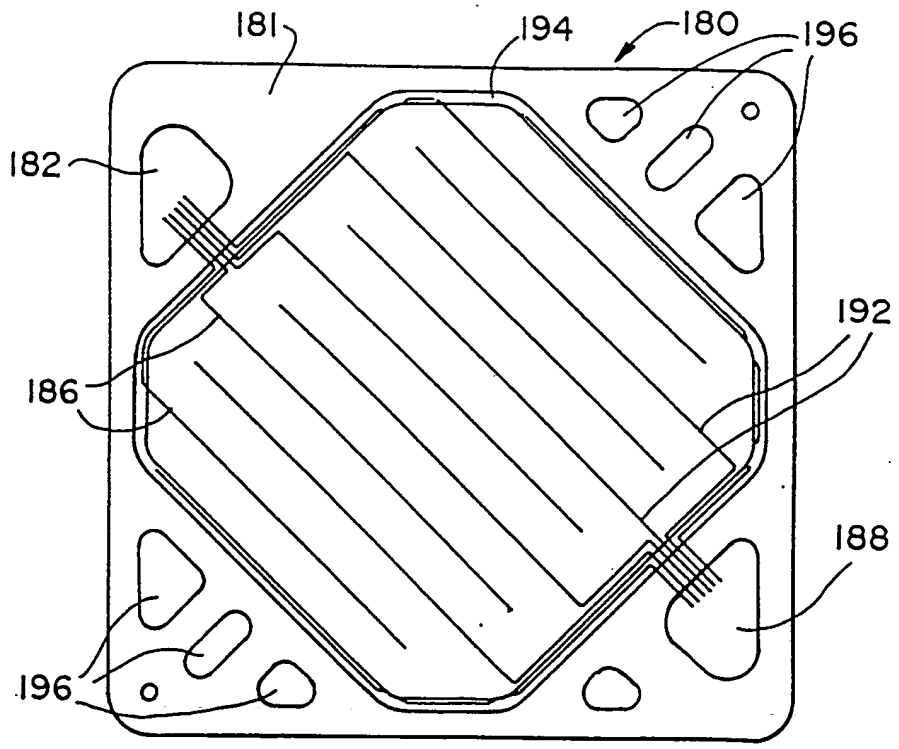
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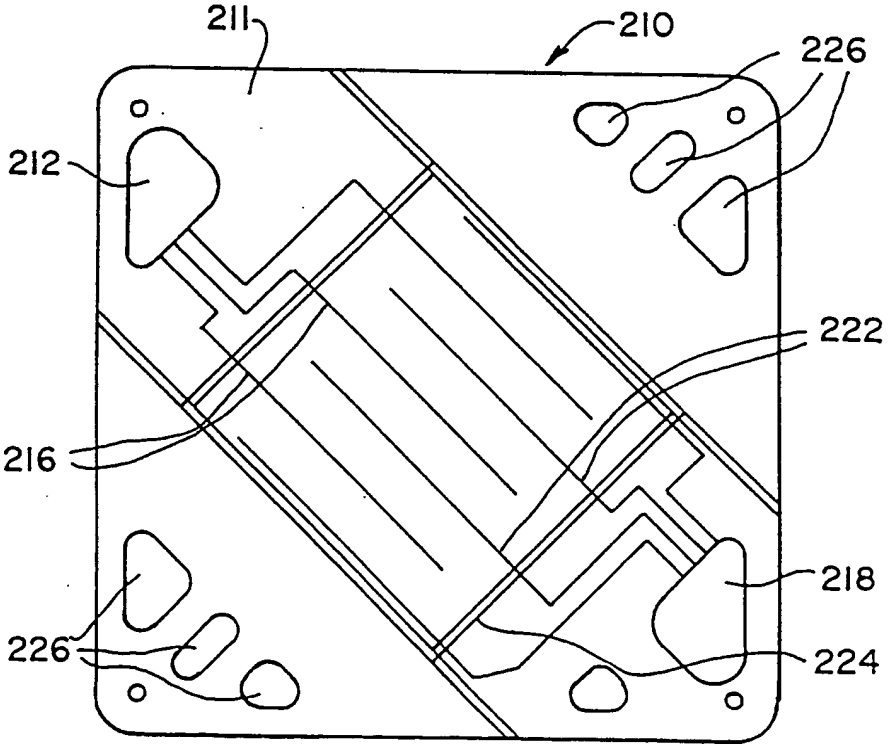
Fig. 9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222
216
218
226
224

Fig. 10

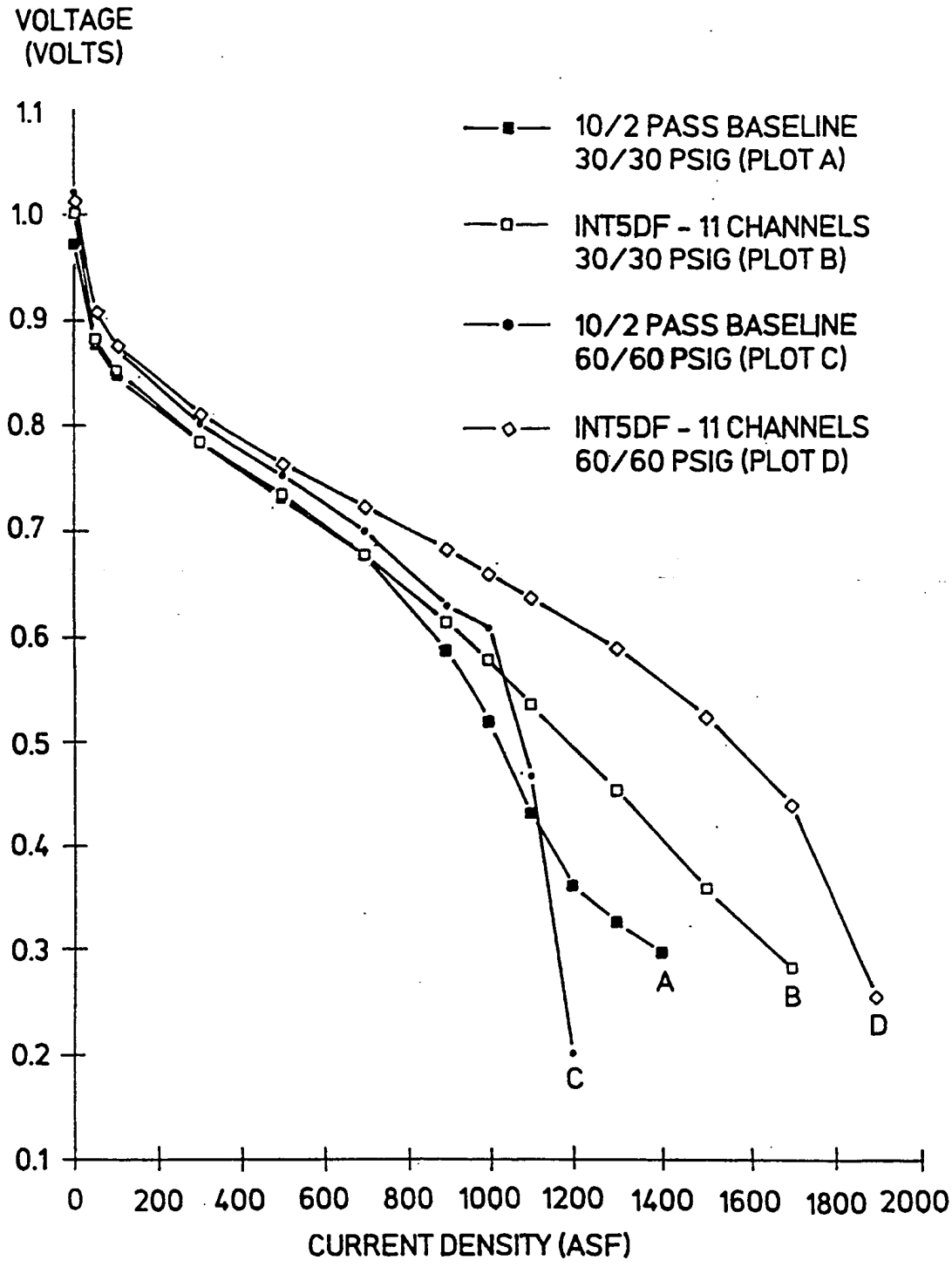

VOLTAGE
(VOLTS)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
10/2 PASS BASELINE
30/30 PSIG (PLOT A)
INT5DF - 11 CHANNELS
30/30 PSIG (PLOT B)
10/2 PASS BASELINE
60/60 PSIG (PLOT C)
INT5DF - 11 CHANNELS
60/60 PSIG (PLOT D)
A
B
C
D
0
200
400
600
800
1000
1200
1400
1600
1800
2000
CURRENT DENSITY (ASF)

Fig. 11

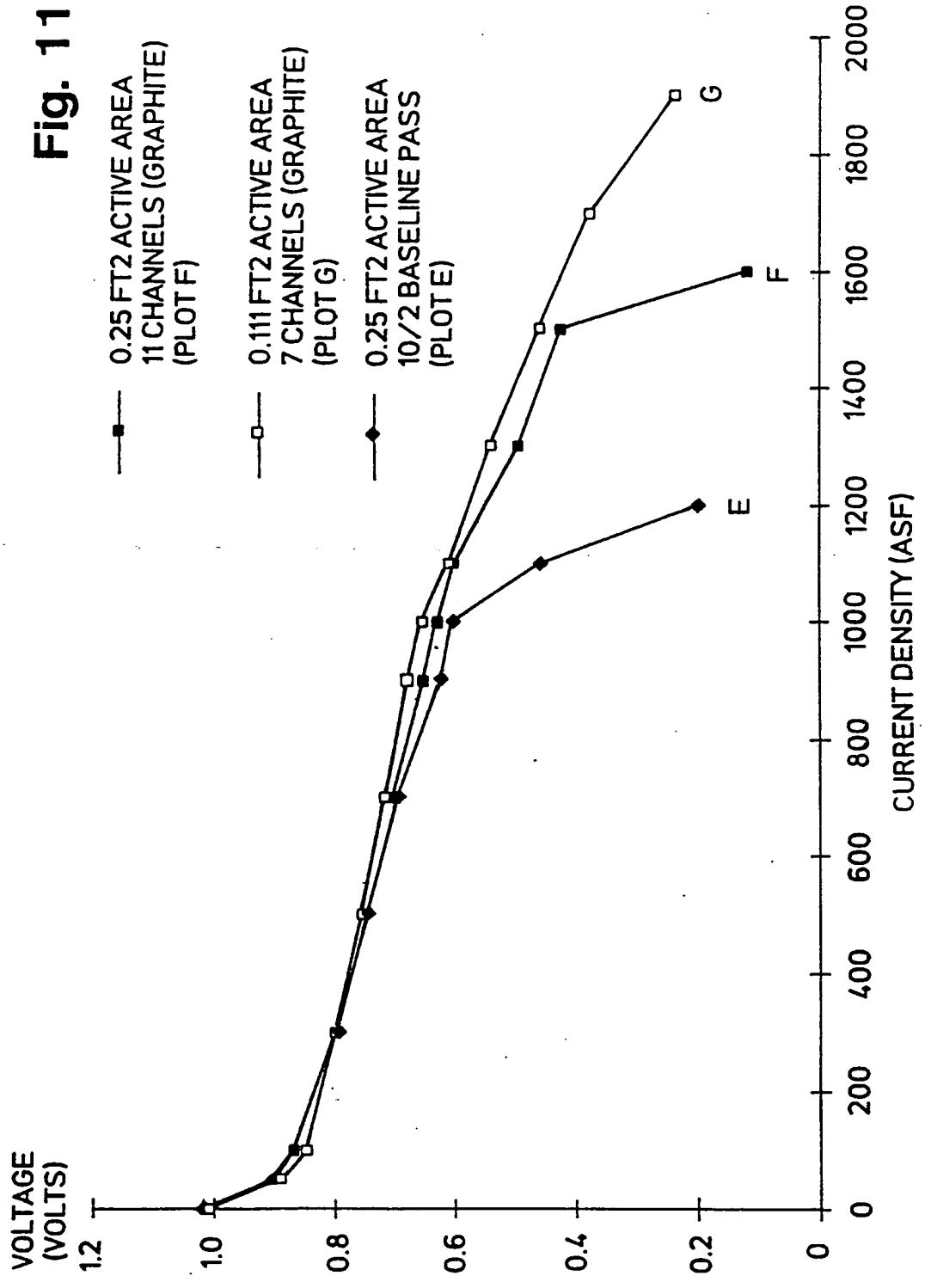

0.25 FT2 ACTIVE AREA
11 CHANNELS (GRAPHITE)
(PLOT F)
0.111 FT2 ACTIVE AREA
7 CHANNELS (GRAPHITE)
(PLOT G)
0.25 FT2 ACTIVE AREA
10/2 BASELINE PASS
(PLOT E)
VOLTAGE (VOLTS)
1.2
1.0
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
CURRENT DENSITY (ASF)
G
F
E

Fig. 12

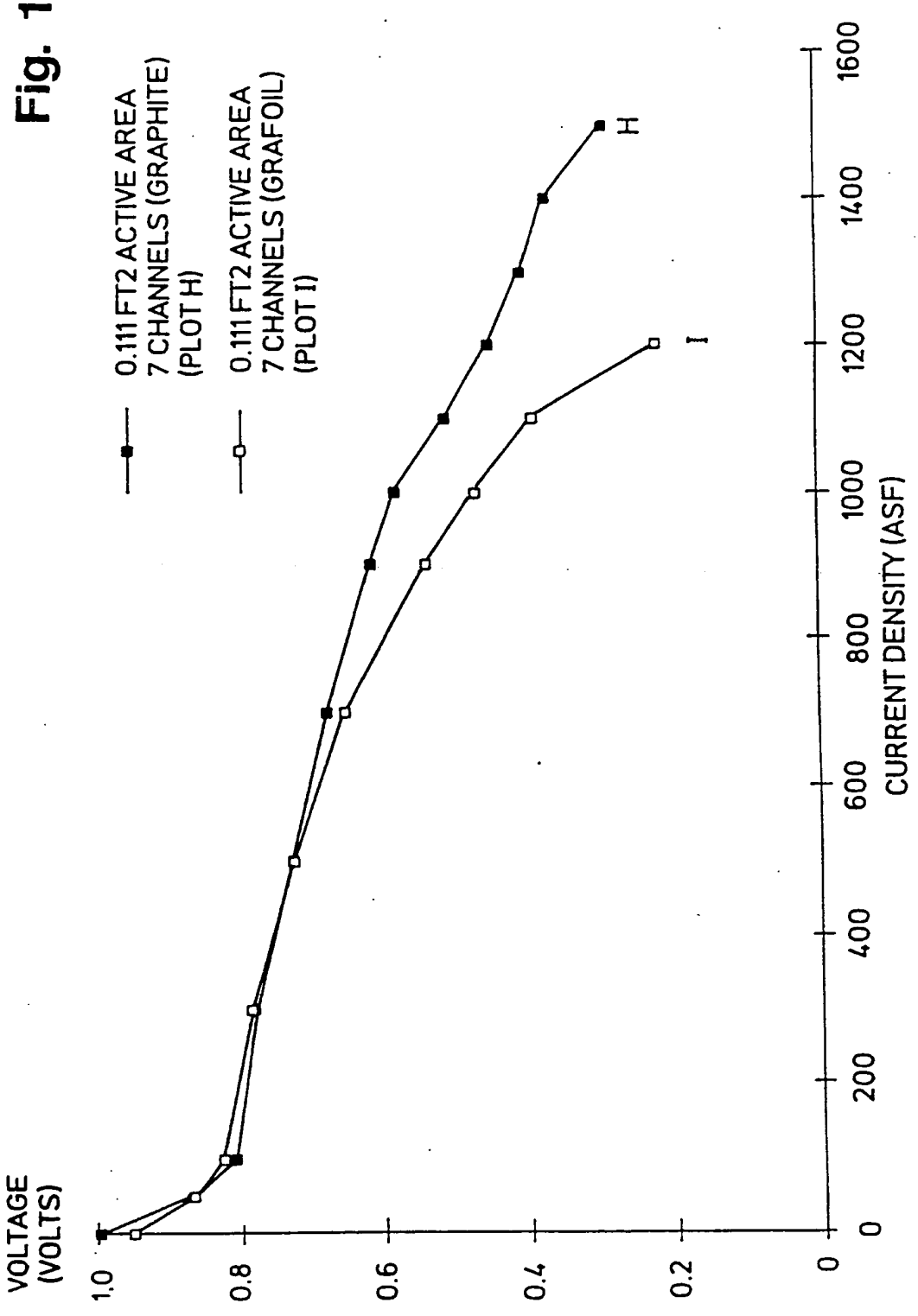
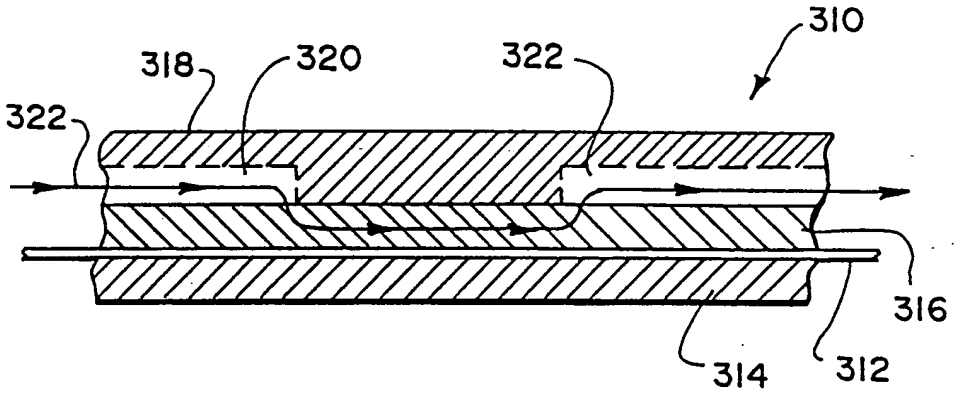

0.111 FT2 ACTIVE AREA
7 CHANNELS (GRAPHITE)
(PLOT H)
0.111 FT2 ACTIVE AREA
7 CHANNELS (GRAFOIL)
(PLOT I)
H
I
VOLTAGE
(VOLTS)
1.0
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
1200
1400
1600
CURRENT DENSITY (ASF)

Fig. 13



INTERNATIONAL SEARCH REPORT

Inte. ional Application No
PCT/CA 93/00486

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H01M8/02 H01M4/86 H01M8/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB,A,959 557 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 3 June 1964 see page 2, line 14 - line 40; figures 1-4 see page 2, line 119 - line 125 see page 1, line 28 - line 36	1-12
X	US,A,4 615 955 (KOJI AMAKAWA ET AL) 7 October 1986 see claim 1; figures 9,10 see column 4, line 62 - column 5, line 28 see column 5, line 65 - column 6, line 8	1,2,5,6, 13,16-18
Y		31, 34-37, 40-42

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 February 1994	09. 03. 94

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 10, no. 82 (E-392)(2139) 2 April 1986 & JP,A,60 227 361 (FUJI DENKI SOUGOU KENKYUSHO) 12 November 1985 see abstract	1,2,5-7, 10-12
Y		19, 22-25, 28-30
X	GB,A,1 151 373 (ENERGY CONVERSION LIMITED) 7 May 1969 see claims 1,14; figures 1,4 see page 2, line 102 - line 116	1-12
Y		19, 22-25, 28-30
Y	WO,A,84 02429 (AB OLLE LINDSTRÖM) 21 June 1984 see claims 1,3,5; figure 7 see page 9, last paragraph	19, 22-25, 28-31, 34-37, 40-42
Y	DE,A,18 14 702 (GENERAL ELECTRIC COMPANY) 10 July 1969 see claims 1,2,4,5; figures 1,4	19, 22-25, 28-31, 34-37, 40-42
X	PATENT ABSTRACTS OF JAPAN vol. 8, no. 111 (E-246)(1548) 24 May 1984 & JP,A,59 027 465 (TOKYO DENRYOKU K.K.) 13 February 1984 see abstract	1,2,5-7, 10-12
X	PATENT ABSTRACTS OF JAPAN vol. 10, no. 317 (E-449)(2373) 28 October 1986 & JP,A,61 128 470 (HITACHI LTD) 16 June 1986 see abstract	1,2,7
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INTERNATIONAL SEARCH REPORT

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Inte. ..onal Application No
PCT/CA 93/00486

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